

Electronic Version

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Description

ELECTRON BEAM POSITION REFERENCE SYSTEM

BACKGROUND OF INVENTION

[0001] The field of the invention is that of vacuum technology, and in particular that of electron beam technology.

[0002] Electron beam (e-beam) lithography tools are commonly used in semiconductor manufacturing to form sub-micron shapes on a semiconductor wafer. Shapes are formed by directing a beam of electrons from a source at one end of a column onto a photoresistive layer on a substrate at an opposite end of the column. A typical substrate may be 200 mm - 300 mm in diameter or larger. These submicron shapes may be formed either by writing the shape directly onto a photoresistive layer on the substrate, wherein the substrate is a semiconductor wafer; or, by writing the shape onto a photoresistive layer on a substrate which is used as a mask, subsequently, to print the shape onto the semiconductor wafer.

[0003] Further, there are two broad types of writing modes used in electron beam lithography. The first type is referred to as "blind mode" or a "dead reckoning mode" and is commonly used in mask making. In the blind mode, the substrate is a featureless blank coated with resist and

all of the patterns are placed by dead reckoning. The second mode, which may be referred to as the "registered write mode" or a "direct write mode," is commonly used in direct write applications, i.e. writing directly onto a semiconductor wafer, in what are referred to as device fabrication runs. In the registered write mode case, the patterns must be precisely located relative to previous levels which requires registration targets built into each level and the substrate as well. Regardless of the mode employed, accurately placing or repeating sub-micron shapes at precise locations across a distance of 200-300 mm demands precise beam registration.

[0004] However, even if the beam is registered adequately when pattern printing begins, during the course of writing the pattern, the e-beam may exhibit what is referred to as drift, i.e., exhibiting increasing inaccuracy in one direction as time passes. So, in order to maintain adequate precision, pattern writing may be interrupted periodically, depending on the particular tool's inherent e-beam drift, to check tool registration and, whenever registration error exceeds an acceptable tolerance, to adjust the beam.

[0005] Normally, the substrate is held on a stage opposite (beneath) the beam source and this registration measurement involves diverting the stage to position a registration target under the beam. Then, the beam is scanned over the registration target, the target's location is measured and the target's measured location is compared against an expected result. Any measured errors are corrected by adjusting the beam or

adjusting stage positional controls. Then, the stage is returned to its former position to resume writing the mask pattern. This measurement and reregistration can be time consuming.

[0006] Furthermore, for this e-beam registration approach, the registration measurement takes place at a stage location other than where the pattern is actually written. Consequently, even after measuring and correcting errors, moving the stage back into position from the measurement area may actually introduce errors, such as from the stage slipping or from other move related stresses. Also, to assure complete accuracy, the beam should be reregistered, frequently, preferably at each field. However, when throughput is a consideration, as it nearly always is, it is impractical to correct the beam registration prior to printing each field.

[0007] U.S. Pat. No. 6,437,347, entitled "Target Locking System for Electron Beam Lithography" to Hartley et al., teaches an e-beam exposure system that may use the invention in its calibration subsystem. This system uses a field locking target that includes alignment marks.

[0008] The '347 patent shows an e-beam lithographic system capable of in situ registration. The preferred system is a Variable Axis Immersion Lens (VAIL) e-beam system and is a double hierarchy deflection system. A controllable stage moves a substrate with respect to the beam axis placing the intended substrate writing field within an aperture on a field locking target. The field locking target is located between the optics section and the substrate and the aperture is sized to permit the beam

to write the field. The field locking target includes alignment marks around the aperture. A differential interferometric system measures the relative positions of the field locking target and the stage. As the stage is moving into position for writing a field, the beam is swept to hit the alignment marks, checking system alignment. The beam control data (coil currents and electrostatic deflection plate voltages) required to hit the marks are stored, and drift correction values calculated and the field beam control data adjusted accordingly.

[0009] Figure 5 shows a cross-sectional diagram of a typical e-beam lithography system 500. This system includes an optics section 502 with a registration focus coil 504a, an autofocus coil 504b, beam deflection coils 506, 508, a projection lens axis shifting yoke 510 and beam deflection plates 511.

[0010] An e-beam source 90 emits a beam represented by arrow 512, which, during writing, travels to a target field on a substrate held on carrier 514. Autofocus coil 504b adjusts beam focus for target height variations resulting from substrate imperfections, thickness variations, etc. In the preferred VAIL lens system, double deflection yokes 506, 508 magnetically deflect the beam 512; and axis shifting coil 510 shifts the variable axis of the projection lens to follow the deflected beam 512. The relatively slow magnetic deflection from coils 506, 508 determines the subfield location, while within the subfield, the beam 512 is deflected by the high speed electrostatic deflection plates 511.

[0011] A passive field locking target 516 permits the beam 512 to write the

pattern in the substrate's target field through an aperture 518. The preferred aperture is rectangular and is large enough to permit writing an entire field. During normal pattern writing, substrate subfields are placed within the field locking target aperture 518 and electrostatic deflection is used to write spots which form the pattern shapes. During registration, the subfield is defined as being over marks on the field locking target 516 adjacent to the aperture 518; and, the beam is deflected accordingly, as represented by arrows 512'. Then, the marks on the field locking target 516 are scanned, in situ, with the electrostatic deflection, to provide near real time positional feedback information.

[0012] For tracking and selecting stage location, the e-beam system 500 includes a differential interferometric system 520. The interferometric system 520 directs a laser, represented by arrows 522, to laser targets 524 and 524' to measure the relative position of the field locking target 516 to the stage mirror assembly 526. Laser target 524 is mechanically coupled to field locking target 516 and laser target 524' is attached to a stage mirror assembly 526. The carrier 514 is kinematically clamped to the stage mirror assembly 526 at points 528. The stage mirror assembly 526, in turn, is flexure mounted to a stage base 530 at points 532. An x or y drive 534 is attached to an appropriate side of the stage base 530 to drive the stage, typically under computer control, in the x or y direction; and, once in place, to lock the stage in place. A mechanical centering adjustment 536 provides a fine adjustment for the field locking target 516 to precisely place it with respect to the beam.

[0013] There is a need for a system in which the position of the electron beam in space is more directly related to the workpiece. In particular, the position of the workpiece being illuminated with a pattern by the beam must be repeatably located in space in order to align the various components of the pattern being written.

SUMMARY OF INVENTION

[0014] The present invention addresses the above-described need by providing an apparatus for relating the actual beam position with the actual mechanical position of a mechanical reference in an electron beam system.

[0015] A feature of the invention is the provision of a mounting plate that supports an e-beam target and a fixed laser target that is adjustable to normalize the reference laser beams.

[0016] Another feature is the ability for XY translation of the field locking target in a vacuum environment actuated from atmosphere.

[0017] Another feature of the invention is a clamping system for the application of clamping force in a vacuum environment where fine adjustment of the clamping force is not possible.

[0018] Yet another feature of the invention is a force application system in which a sizable clamping force is applied through a member that does not permit the application of a transverse force.

BRIEF DESCRIPTION OF DRAWINGS

[0019] Figure 1 shows an exploded view of an embodiment of the invention.